# DESIGN OF BARE OPEN WIRE PLANT

Purpose: The purpose of this addendum is to correct an error in Table 1. The line wire characteristics for the .080-30% copper-covered steel wire were inadvertently listed under the heading for .080-40% copper-covered steel wire; and the line wire characteristics for the .080-40% copper-covered steel wire were inadvertently listed under the heading for the .080-30% copper-covered steel wire.

Deletions and Additions: Strike out the heading ".080-40%HS" on page 26 and add the heading ".080-30% EHS" directly below it.

Strike out the heading ".080-30% EHS" on page 27 and add the heading ".080-40% HS" directly above it.

The second sentence from the top on page 14 should read as follows:

"In relatively dry uncontaminated rural atmospheres the loss in weight of wire with the commonly used Class A galvanizing may be less than ten percent at the end of twenty years, with considerable surface of the wire still zinc coated."

# DESIGN OF BARE OPEN WIRE PLANT

CONTENTS



## 1. GENERAL

1.01 This section is intended to provide REA borrowers, consulting engineers, contractors, and other interested parties with technical information for use in the design and construction of REA borrowers' telephone systems. It discusses in particular some of the factors involved in the design of bare open wire telephone plant.

1.02 This section replaces REA TE & CM-615, I-
January 1961, and its addenda.
thorough discussion of lin-
practices for wires which
when used in windy areas,
long spans, and to bring i
in the March 1962 issue of
Contract," REA Form 511,
open wire plant.

1.03 In designing open wire plant useful information can be found in the following REA publications and their addenda, which are referred to in appropriate places herein:

REA TE & CM Sections:
205 Preparation of an Area Coverage Design
206 Preparation of an Area Coverage Survey
210 Telephone System Design Criteria - Engineering Time Periods
212 Ringing Systems
218 Plant Annual Cost Data for System Design Purposes
319 Interoffice Trunking and Signaling
406 Attenuation Data
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616 Construction of Bare Open Wire Plant
619 Design and Construction of Insulated Line Wire
625 Open Wire Pole Top Assembly Units
626 Staking
670 Corrosion Considerations in Outside Plant
690 Joint Use of Poles
REA Form 511 Telephone System Construction Contract
REA Form 525 Central Office Equipment Specification

## 2. ECONOMIC AND SERVICE CONSIDERATIONS - SUBSCRIBER CIRCUITS

the maximum line capacity except where this is not possible because of transmission and signaling requirements. Systems in the Plains States may possibly, out of necessity, exceed the 10 wire limit.

2.02 Cable has higher dc resistance than open wire which limits its signaling ranges. It also has higher attenuation which limits its transmission ranges for both voice and carrier frequencies. Therefore, for longer circuits, open wire may be required in a portion of a circuit to reduce the circuit resistance and attenuation to meet the signaling and transmission requirements.

2.03 Where extensive trimming is required, it generally will be more economical to use aerial cable or distribution wire in lieu of open wire if transmission and signaling ranges permit. However, insulated open wire has been used satisfactorily as an insert in thickly wooded areas. Where the terrain is favorable to plowing operations, buried plant may be the economical choice for the major part of a telephone system. Where the terrain is flat or gently rolling and subscriber density is low, insulated extra long span open wire should be considered.

2.04 In addition to the comparison of initial costs, the depreciation rates, maintenance and other annual costs of open wire plant must be compared with these costs for other types of plant before a decision is made to use open wire.

2.05 The effect of atmospheric conditions upon the life of bare line wire may dictate the use of insulated wire in certain areas. Atmopheric effects on line wire and the use of insulated open wire are explained in REA TE & CM-619 and -670.

2.06 Steel line wire generally is satisfactory from the transmission standpoint for subscriber circuits if the signaling requirements are met and if the use of carrier equipment is not contemplated. However, the use of subscriber carrier to provide for additional growth and service upgrading is rapidly increasing due to improvements and declining costs of carrier equipment, as well as subscriber demands for better grades of service. Therefore, the use of steel should be limited so that subscriber carrier may be added at a later date if service upgrading is desired. TE & CM-406 presents carrier frequency attenuation data for steel line wire. Copper-covered steel and aluminum-covered steel line wire provide a satisfactory transmission path at carrier frequencies for considerably greater distances than steel wire. The span lengths now achievable with copper-covered steel and aluminum-covered steel wire are

comparable to those obtained with extra-high strength steel wire. The advisability of at least one copper-covered or aluminum-covered pair should be considered on each multi-circuit open wire lead to provide capability for future carrier applications.

2.07 The required span lengths for a particular open wire application depend upon the strength of the wire involved and on the storm loading conditions in the area. A system should be designed to have the longest spans practicable. In joint construction the span lengths are usually already determined. Uniform span lengths are desirable with every transposition system acceptable for use by REA borrowers, though the basic length limit may vary for different types of conductors. The only exception to the above statements may be the REA-1 or other carrier transposition systems which have been engineered to accommodate a large number of high frequency carrier systems and which should have a 300' or less average span length when more than two physical circuits using the same frequencies are present. Paragraph 6.03 discusses span lengths in further detail.

## 3. ECONOMIC AND SERVICE CONSIDERATIONS - TOLL AND EAS TRUNK CIRCUITS

3.01 For toll and EAS trunk circuits the type of plant most suited for a particular situation depends on annual costs, consistent with transmission and signaling requirements. Such things as tree and brush conditions, type of soil, expected traffic density and atmospheric conditions are reflected in the annual cost considerations. The number of trunks required is determined as stated in REA TE & CM-500. A feasibility study on the annual cost basis should consider all factors with regard to initial circuit requirements and projected growth, as well as terrain and vulnerability to storm damage. This study when considered in connection with the annual costs, should deter-

Where transmission is critical, as for toll trunks, cable carrier should be investigated. The use of repeaters and loading will make voice frequency cable circuits more advantageous for greater distances.

3.02 In order to make an annual cost study of cable versus open wire it is necessary to make a preliminary decision as to the type of line wire to be used. Because of transmission limitations, galvanized steel wire is not recommended for toll or EAS trunk circuits, particularly if carrier use is contemplated. Consequently, for carrier leads, the choice of wire usually will be copper-covered steel or aluminum-covered steel. Where transmission on voice frequency circuits is not a problem, and future carrier application is not contemplated, galvanized steel line wire may be considered.

## 4. TYPES OF LINE WIRE

4.01 The three types of line wire approved for use on the systems of REA borrowers are galvanized steel, copper-covered steel, and aluminum-covered steel. The most commonly used gauges and strengths are indicated in Table 1. The dc conductivity of copper-covered steel wire is expressed in percent of the dc conductivity of a pure annealed copper wire of the same diameter. The three values of conductivity available in copper-covered steel wires now acceptable for use by REA borrowers are 25, 30, and 40 percent.

4.02 The long spans obtainable and the low costs of .109-195 steel, .080-25% copper-covered steel, and .091-inch aluminum-covered steel make them especially attractive in reducing the initial as well as the annual charges. It is recommended that these three conductors be used to the fullest extent possible.

4.05 The only aluminum-covered steel conductor now approved for use by REA borrowers has a diameter of .091-inch. It consists of a steel core covered with aluminum. The voice and carrier frequency transmission characteristics of the .091 inch aluminum-covered steel line wire and the .080-25% copper-covered steel line wire are comparable. This conductor will offer substantial benefit in corrosive atmospheres such as are present near oil refineries, oil wells, paper mills, sour gas fields and sulphur mines. This conductor is now being evaluated for use in marine atmospheres. Until conclusive results are obtained from the exposure sites, the use of this conductor in coastal and other salt spray areas is not recommended. Table 1 and REA TE & CM-670 gives guidance as to the choice of suitable metals for various atmospheres.

5. PHYSICAL PROPERTIES OF LINE WIRE

5.01 The physical properties of line wire, as they relate to the design of telephone plant, with applicable numerical data are summarized in Table 1 for the commonly used gauges and types of wire when new. These physical properties of wire have considerable effect upon the life of the plant. They also affect the sag and tension developed in open wire construction and have been taken into consideration in the development of sag and tension data.

5.02 Minimum Breaking Strength: The minimum breaking strength of line wire, as determined from tests on a large number of samples, is the minimum value of in-line tension required to break the wire. Galvanized steel and copper-covered steel wires differ from aluminum-covered steel in that they have more than one value of breaking strength for each diameter depending upon their grade of steel. The strength of galvanized steel, aluminum-covered steel and copper-covered steel wire is not appreciably affected by handling during construction provided care is taken to prevent damage to the surface of the wire. Proper storage of wire coils to prevent damage is explained in REA TE & CM-616. Nicks or severe abrasions on the surface of the wire produce points of

5.03 Elongation: When storm loads are applied to a line wire, the tension in the wire increases and causes an increase in the length of the wire. When the load is removed the wire may not return to its original length. The elongation remaining after the load has been removed is referred to as "permanent stretch." Under extreme loading conditions the wire may continue to elongate even though the load remains constant. This phenomenon is called creep. This may cause failure of the wire as a result of the reduction in cross sectional area. Such failures are rare, however, and should not occur if the wire is strung in accordance with the stringing sags recommended by the wire manufacturers.

5.04 Elastic Limit: The term elastic limit as used herein indicates the maximum tension to which a wire may be subjected without producing a permanent stretch of importance from the standpoint of performance of the plant. An appreciable amount of permanent stretch does not occur in open wire unless a tension of approximately sixty percent of the breaking strength of the wire is exceeded. In the cases where an appreciable amount of permanent stretch does occur, resagging of the wire may be required to restore the required minimum ground clearances and/or to minimize midspan hits.

5.05 Temperature Coefficient of Expansion: The wire length decreases with decreasing temperatures and increases with increasing temperatures, resulting in changes in the sag and tension. The temperature coefficient of expansion expresses the change in unit length of wire per degree change in temperature. The sag and tension data for various conductors provide for a wide range of temperature to which the plant may be subjected. Wire placed in plant during moderate temperatures will undergo an increase in sag due to expansion as the temperature increases. If the sag placed in the wire initially is too great, then the increased sag at higher temperatures may result in inadequate ground clearances and increased possibility of midspan hits. If the initial sag is too small, fatigue breaks may result during cold weather.

5.06 Fatigue Endurance Limit: The fatigue endurance limit of undamped line wire, defined as the maximum stress that may be applied for an indefinitely large number of cycles without producing a break, is expressed in pounds per square inch of cross-sectional area of the wire. This value is considerably less than the minimum breaking strength. This is because the minimum breaking strength is based on tension only, whereas the fatigue endurance limit is based on the combined stresses due to static tension and dynamic vibration. The frequency of force of vibration applied to a given conductor due to the wind may be calculated from the equation:

$$F = \frac{KV}{D}$$

Where

F is in cycles per second
V is the wind velocity in feet per second
D is the conductor diameter in feet
K is an emperical constant of approximately 0.21

It may bs seen that the frequency of the applied force increases as the wind velocity increases and is higher for smaller diameter conductors. However, as ice accumulates on the wire the overall diameter increases and the frequency of force decreases. For this reason the fatigue endurance limit is of importance at low temperatures when there is no ice on the wires. Vibration due to wind blowing across the wires is much more severe on unloaded wires than on loaded wires. These vibrations set up high internal stresses which may result in fracture of the wire at a value of tension considerably less than that occurring under storm load. For this reason the unloaded tension at low temperatures must be kept to a reasonable percentage of the fatigue endurance limit.

The recommended maximum tensions are stated in paragraph 6.012. Fractures often referred to as "cold weather breaks" are reduced by the application of vibration dampeners on the wires as explained in paragraph 6.052.

## 6. MECHANICAL CONSIDERATIONS

### 6.01 Sag and Tension

6.011 The sag in a line wire is the maximum distance measured vertically from the lowest point in the wire span to a straight line joining the points of support. It is dependent upon the weight of the wire, the span length and the tension in the wire. The sag in a span of telephone line wire is adequately approximated by the parabolic formula:

$$S = \frac{1.5\ WL^2}{T}$$

Where S = sag in inches
L = span length in feet
T = tension at the supports in pounds
W = weight of wire or resultant weight of wire and storm load in pounds per foot of wire.

6.012 Each sag value stated in the sag and tension tables mentioned below is applicable in wire stringing for a specified temperature. A change in temperature will cause a change in sag and tension due to the elongation or contraction of the wire as stated in paragraph 5.05. Wire line design must take into consideration the complete range of atmospheric conditions to which the line will be subjected. Temperatures may range from as low as -40°F. to as high as 120°F. Severe ice storms and high winds may cause very high stresses in the wire. The NESC divides the United States into heavy, medium, and light loading districts. For design purposes the NESC adopted storm loading conditions in these districts based on experience. A pole line should be designed to meet the storm loading conditions for the district in which it is to be located. Local experience may justify the use of heavier loading in some locations. For example, a hilltop in the medium loading district may have a record of heavy ice which may warrant considering it as a heavy loading area. The wire manufacturers have compiled sag and tension data for various span lengths, temperatures and loading districts for the commonly used wires. These data are for conditions of wind and ice for the three loading districts defined in the NESC and are available from the wire manufacturers in the form of engineering handbooks which are approved for REA borrower's use and, in general, are based upon the following design limits:

a. The unloaded tension in the conductor shall not exceed 75 percent of the fatigue endurance limit at 0°F for all loading areas.

b. The tension in the maximum span under NESC assumed storm loading shall not exceed the following percentages of the minimum breaking strength of the wire:

Heavy Loading District . . . . . . . . . . . . 85%
Medium Loading District . . . . . . . . . . . 75%
Light Loading District . . . . . . . . . . . . 60%

Note: Individual span lengths greater than the maximum shown by wire manufacturers are permissible. However, the average of the length of the increased span and the three spans on either side of the increased span should not exceed the maximum recommended span.

Example: Assume that the maximum recommended span length is 480 feet. If we have span lengths as follows: 450, 480, 400, 520, 430, 460, and 400, the average is 447 feet. Therefore, the 520 foot span is permissible.

6.013 The maximum span lengths as determined by the wire manufacturers are developed to produce sags which are capable of obtaining NESC ground clearances with economical pole heights and still remain within the maximum load limitations set forth above. In general, the less initial tension placed in a conductor, the greater the span length possible. However, the savings realized in the increased span lengths could be offset by the cost of taller poles to obtain ground clearance.

6.02 Storm Loading: The NESC assumed storm loading mentioned in the above paragraph is as follows:

6.021 The vertical component of the load is that due to the weight of the wire alone plus the weight of a specified ice coating and is determined for a round conductor from the equation:

$$V = W + 1.24\ R\ (D + R)$$

Where V = vertical component of load in pounds per foot
W = weight of wire in pounds per foot
R = radial thickness of ice in inches
D = diameter of wire in inches

6.022 The horizontal component of the load per foot of wire is that due to a specified wind pressure acting upon the projected area* of the ice-coated wire and is determined from the equation:

$$H = \frac{P\ (D + 2R)}{12}$$

Where H = horizontal component of load in pounds per foot
P = wind pressure in pounds per square foot
R and D are the same as above

*The "projected area" of a bare or ice coated wire is a flat surface having a width equal to the vertical diameter of the bare or ice coated wire and is measured in square feet.

6.023 The resultant load ($W_l$) is equal to the square root of the sum of the squares of the vertical and horizontal components plus a specified constant (C) and is determined from the equation:

$$W_l = \sqrt{H^2 + V^2} + C$$

This value is to be used in the equation given in paragraph 6.011 when calculating sag under storm load.

6.024 The constant (C) shown in the previous paragraph is added as an extra margin of safety for loads which might occur in excess of those assumed in the NESC. The data to be used in the above equations in determining the resultant storm load are summarized in Table A.

TABLE A
National Electrical Safety Code Loading

| | Storm Loading District | | |
|---|---|---|---|
| | Heavy(H) | Med.(M) | Light(L) |
| Radial Thickness of Ice (In.) | 0.50 | 0.25 | None |
| Horizontal Wind Pressure Lbs. Per Sq. Ft. of Projected Area | 4 | 4 | 9 |
| Constant for Bare Line Wire (C) | 0.29 | 0.19 | 0.05 |
| Constant for Insulated Line Wire (C) | 0.31 | 0.22 | 0.05 |
| Design Temperature | 0°F | 15°F | 30°F |

6.03 Span Lengths Permissible for Various Types and Gauges of Wire

6.031 Maximum span lengths recommen
for the more commonly
in Table 1. Poles o
using these data in accordance with REA TE & CM-611. Pole
heights must be based on the requirements of REA TE & CM-602 and the manufacturer's recommended stringing sags at 60°F.

6.032 As pointed out in paragraph 4.02, the use of 109-195 galvanized steel, .080-25% copper-steel and the .091-inch aluminum steel will provide lower construction costs. In addition reduced leakage for bare wires will result because of the lesser number of poles, crossarms and insulators required.

6.033 The maximum sag to be expected under storm loading may be calculated as follows for the heavy loading district:

Facility - .109-195 galvanized steel
Wt. per foot - .0322 lb./ft.
Maximum tension - .85 x 1800 = 1530 pounds
Span length - 600 ft.

$$V = W + 1.24R\ (D+R)$$
$$= .0322 + 1.24 \times .5\ (.109 + .5)$$
$$= .41 \text{ lb./ft.}$$

$$H = P\ (D + 2R) \div 12$$
$$= 4\ (.109 + 1) \div 12$$
$$= .37$$

$$W_i = \sqrt{H^2 + V^2} + C$$
$$= \sqrt{(.41)^2 + (.37)^2} + .29$$
$$= .842$$

$$S = 1.5WL^2 \div T$$
$$= 1.5 \times .842 \times 600^2 \div 1530$$
$$= 297 \text{ inches}$$
$$= 25 \text{ feet}$$

Sag increase = 25 - 5 = 20 feet

Therefore, it may be seen that when these longer spans are used, the resulting sag to be expected under the NESC assumed storm loading would tend to have the conductors lie on the ground and relieve the load before the conductor reaches a dangerous stress level.

tacts between bare wires in a span are
an hits. The frequency of midspan hits is
on the wire configuration used, pin spacing,
amount and uniformity of sag, wind gust
direction, and frequency of wind gusts, and
ot the windward wire of a pair has the greater
ere is a sag difference in the two wires.
cause false operation of central office
i may damage the equipment resulting in
s of service and annoyance to customers.
ith greater frequency in windy areas and
s where considerable sag is present in the
hits are particularly objectionable on
its because they affect all channels as
hysical circuit.

6.042 To minimize midspan hits in the windy areas, it is recommended that point type transposition brackets be used. This bracket provides uniform conductor separations and its use has minimized the midspan hit problem. The following areas are usually considered to be windy: New Mexico, Iowa, Kansas, Minnesota, Nebraska, North Dakota, Oklahoma, South Dakota, and the heavy loading districts of Texas, Colorado, Wyoming, and all other areas where local experience indicates that midspan hits may be a problem. All the wires in a span must be sagged evenly.

## 6.05 Fatigue Failure

6.051 The fatigue endurance limit of line wire was defined in paragraph 5.06. The stresses set up in a wire are a combination of the static stresses and the dynamic stresses set up by vibration caused by wind blowing across the line. Vibration caused by wind is a vertical oscillation of a wire. The damaging forces are greatest near the supports and rigid type fittings. If the magnitude and duration of the force of vibration are sufficiently high, they will cause wire breaks at the supports and rigid fittings.

6.052 The probability of fatigue failure is increased as the tension and span length are increased and the diameter of the wire is decreased. Therefore, preventive measures are required for the small diameter, high strength conductors. The installation of vibration dampers which are described in paragraph 12 virtually prevents line wire vibration and fatigue failure.

coating. In contaminated areas the zinc may all disappear in much less than twenty years. In relatively dry uncontaminated rural atmospheres the loss in weight of wire with the commonly used Class A galvanizing may be less than the percent at the end of twenty-years, with considerable surface of the wire still zinc-coated. Where the atmosphere is contaminated by factory fumes, either aluminum-covered steel or insulated wire may be used; but, in coastal areas, polyethylene-insulated line wire has proved to be most effective against the corrosive atmosphere. Insulated wire has the added advantage of eliminating the harmful effects of midspan hits. The type of wire to be insulated should be chosen on the basis of electrical and physical requirements since all types of wire can be insulated. In an area where a corrosive atmosphere may exist, consultation with neighboring operating companies may be of benefit in selecting the areas within the operating boundaries of the company where insulated line wire should be used. REA TE & CM -619 provides detailed information on insulated wire plant design and construction. REA TE & CM-218 contains maps of the United States indicating the general corrosion areas and gives the depreciation rates for both insulated and bare galvanized steel and copper-covered steel wires. For a more detailed explanation on corrosion refer to REA TE & CM-670. Table 1 gives relative performance of the commonly used conductors in various atmospheres.

## 7. ELECTRICAL CONSIDERATIONS

### 7.01 Subscriber Circuits

7.011 Some rural subscriber circuits may require open wire beyond the end of a cable or distribution wire. Signaling usually governs the type of open wire chosen for voice frequency subscriber circuits because transmission is satisfactory for greater distances than is signaling with many combinations of wire and cable. If a proposed circuit exceeds the permissible signaling loop resistance for the particular type of central office involved, one of three alternatives may be adopted. The first alternative is to have the cable portion of the circuit consist of cable of lower resistance than first contemplated, or the use of a composite cable may be considered. REA TE & CM-422 gives cable resistances. The second alternative is to use a type of open wire having lower resistance. The third alternative is to use a long line adapter and increased battery on the proposed circuit. The choice should be based upon the economics involved in the particular situation.

7.012 Transmission usually governs the choice of open wire for carrier frequency subscriber circuits. The carrier frequency transmission losses for steel wire are considerably higher than those for other types of line wire. Consequently, steel wire should not be considered if carrier use is contemplated. However, steel wire may be used beyond the carrier terminal to individual subscribers.

7.013 In those cases where low loss wire is selected for part of a circuit and galvanized steel wire for the remainder the low loss wire should be placed at the central office end of the circuit. This is desirable because of the possible future application of subscriber carrier to the circuit.

7.014 Where the REA-1 transposition system is used all line wire on the pole line used for carrier frequency transmission must be of the same type and gauge.

7.02 Toll and EAS Trunk Circuits

7.021 For some projects the type of trunk signaling is predetermined; for example, where it must be the same as the type of equipment used at the distant office on other trunk routes. In such cases the type of signaling equipment used may determine the choice of line wire based on resistance limitations.

7.022 Copper-covered steel or aluminum-covered steel wire is recommended for all of the open wire used in trunk circuits. The several types of signaling and their signaling leg or loop resistances are stated in REA TE & CM-319.

7.023 Where a choice of signaling
transmission requirements w
type of open wire.

## 8. TRANSPOSITION SYSTEMS

8.01 There are four types of transposition systems presently recommended for use on REA borrowers' system. These are R1, R2, REA-1, and REA V-1 systems.

8.02 REA TE & CM-462, describes systems which are designed primarily for pole lines having only voice frequency circuits although a limited number of carrier channels can be used. REA TE & CM -463, describes systems which are designed for pole lines having a number of similar high frequency carrier circuits. REA TE & CM-465, describes a system which is designed for use in windy areas on single circuit leads limited to voice frequency operation where coordination with the power system must be provided. The applications and limitations of the various transposition systems are given in the sections mentioned.

## 9. POLE TOP ASSEMBLY UNIT APPLICATIONS

9.01 In the design of an open wire pole line several different pole top assembly units may be required on a pole to make a supporting structure for the wires. These units are illustrated with their applications and limitations in REA TE & CM-625. The engineer must select and indicate on the construction drawings or staking sheet which pole top assembly units are to be used on each pole. The items covered in REA TE & CM-625 include crossarms, pins, insulators, transposition brackets and miscellaneous units such as pole ground wires, pole top extensions, lightning arresters, and drainage units. Type B crossarms are used on joint poles to allow for the required 30-inch climbing space.

9.02 Certain span length limitations are suggested in the use of A and B type crossarms, based on the factors involved in the causes of midspan hits mentioned in paragraph 6.041, on transmission considerations and on available field test data. These limitations are not stated in REA TE & CM-625. They are given in the following table.

SPAN LENGTH LIMITS FOR A AND B
TYPE CROSSARMS FOR BARE LINE WIRES

| Type Crossarm | Type Transposition | Pin Spacing-Inches | Span Length-Feet Windy Areas | Span Length-Feet Non-Windy Areas |
|---|---|---|---|---|
| A | R1 & R2, Tandem | 12 to 2-1/2 | 250 | 450 |
| A | R1 & R2, Point | 12 to 12 | 500/1 | 600 + |
| A | REA-1, Point | 12 to 12 | 300/2 | 300/2 |
| A | REA-1, Tandem | 14-1/2 to 2-1/2 | 0/2 | 300/2 |
| B | R1 & R2, Tandem | 10 to 2-1/2 | 200 | 400 |
| B | R1 & R2, Point | 10 to 10 | 350/1 | 600 + |
| B | REA-1, Point | 10 to 10 | 300/2 | 300/2 |

Note:

/1 Insulated wire suggested for longer spans.
/2 Spans longer than 300 feet are not recommended for REA-1 Transposition System because of transmission considerations. Tandem transpositions are not recommended for the REA-1 System on A crossarms in windy areas and no where on B crossarms. See REA TE & CM-463.

## 10. TRANSPOSITION BRACKETS

10.01 The text that follows covers only the mechanical considerations in the choice of transposition brackets.

10.02 Tandem Brackets: There are two types of tandem transposition brackets, one for light duty applications and another for heavy duty applications. These are designated as the T-6 and the T-7 assembly unit, respectively. The T-6 unit is constructed of 3/8" steel with 12-inch pin spacing and the T-7 unit, 1/2" steel with 8-1/2 inch pin spacing. REA TE & CM-625 gives their limitations. Tandem brackets, where applicable, can be used in both joint and non-joint construction, except that their use should be limited to non-windy areas. However, the tandem transposition brackets should not be used in any area where the average span length exceeds 400 feet.

10.03 Point Brackets: Three sizes of point type transposition brackets are acceptable for use by REA borrowers. All three sizes provide for crossing the left wire above the right wire. One size, having a 12-inch wire spacing and 12-inch mounting hole spacing, is designed for use on type A crossarms. This is called the T-18 Assembly Unit. A second size, having a 10-inch wire spacing and 10-inch mounting hole spacing is designed for use on type B crossarms. This is called the T-19 Assembly Unit. Neither of these units is satisfactory for transposing the pole pair of wires on six or ten-pin crossarms because of insufficient clearance between the pole and the adjacent wire. Transposition of this pair is accomplished by means of a point transposition bracket with 8-inch wire spacing and 8-inch mounting hole spacing called the T-20 Assembly Unit. It requires boring one mounting bolt hole on the job in both the A and B type crossarms. A crossarm pin hole with a locust bushing is used for the second mounting bolt. REA TE & CM-625 and Form 511 provide information as to the drilling required to mount this bracket.

0.04 It is recommended that the 12-inch point bracket be used to the fullest extent possible in windy areas.

10.05 Midspan transposition brackets of present designs are not recommended for two major reasons: (1) They cause inequalities of sag between wire pairs. (2) They have poor dc leakage characteristics on a physical circuit.

## 11. LINE WIRE TIES

11.01 Construction practices for line wire require tying of the conductor to the insulators at all non-transposition points and to one of the two insulators the line wire contacts at transposition points, except in the case of railroad crossings which require ties to be made at all insulator contacts. The purpose of the tie is to secure the conductor firmly to the insulator and to prevent slippage of the wire through the tie in case of a wire break or due to unequal loads in adjacent spans. The four types of ties acceptable for bare line wire on REA borrowers' systems are the V-notch splint tie, the prelashed tie, the modified horseshoe tie, and the modified reinforced tie which is used with armor rods for insulated line wire and for certain sizes of bare line wire in windy areas. These ties are shown on guide drawings in REA Form 511.

11.02 The prelashed tie comprises a splint with helical ends for entwining the line wire. The splint is prelashed to the insulator by a tie wire in the shop or on the ground at the job. This provides uniform lashing. The helical ends of the splint are entwined around the line wire by the lineman after the wire has been properly sagged. This tie has an advantage in that it can be removed from the line wire to permit slack pulling in resagging operations and then respun on the line wire without loss of holding power. This is the preferred tie where armor rods are not specified.

11.03 Construction practices have recently been revised to require that where point type transposition systems are used in windy areas, all conductors having a diameter of .104-inch and less are to be provided with armor rods at all points of support. Point type transposition brackets require 30-inch armor rods, and single insulator supports require 12-inch armor rods. A modified reinforced tie shall be used for all ties made where armor rods are installed.

## LICES AND DEADENDS

consist of 18-inch lengths of black poly-
ically to permit placing them on line wires.
a one-quarter inch internal diameter and

one-sixteenth inch wall thickness and move freely along the wires, locating themselves at optimum positions to counteract wire vibration due to wind. These dampers have proven that they reduce the effects of wind induced vibration substantially. It is required that these dampers be applied to all conductors during the stringing operation and a damper be placed on both sides of splices.

12.02 The preformed type deadends and splices are recommended for use throughout the United States with all conductors having a diameter of .104 inch and less. These type fittings have been found to minimize the fatigue problems associated with compression type fittings. However, the compression type splices are permitted and may be used if they are properly installed.

## 13. PIN POSITION ASSIGNMENTS

13.01 Pin numbers are considered to be as shown in Figure 1. These numbers apply at the deadend crossarm at the beginning of an open wire lead. Figure 1 shows the assumed pin numbers as being from left to right as viewed in the direction of the line with the observer's back toward the central office. This numbering plan applies to the pole lines that use either A or B types of crossarms. Pin numbers are never marked on crossarms but are used in pin position assignment on circuit layout drawings, staking sheets, and on other plant operating records.

13.02 The assignment of circuits to specific pin positions involves consideration of the following: the transposition system to be employed, the number of circuits, whether they are subscriber or trunk circuits, whether or not they are to be carrier circuits, the length of the circuits, and the equalizing of the loads on the crossarms, particularly at deadends.

13.03 Pin position assignments are made readily where the R1 and R2 transposition systems are to be used as shown in REA TE & CM-462. Where the REA-1 transpositic templated, it is necessary to review the REA TE & CM-463.

Table B shows the recommended pin positions where the R1 and R2 transposition systems are to be used and if no carrier use is contemplated.

TABLE B

PIN ASSIGNMENTS WITH R1 AND R2 TRANSPOSITIONS
(Where no carrier systems are involved)

| Size Xarms | Pin Use Start of Line | No. of Circuits Dropped | Size of Xarms Beyond Drop-off Point | Pin Use Beyond Drop-off Point |
|---|---|---|---|---|
| 10 pin | 1 - 10 | 1 | 10 pin | 1,2,3,4,7,8,9,10 |
| 10 pin | 1 - 10 | 2 | 6 pin * | 3,4,5,6,7,8 |
| 10 pin | 1 - 10 | 3 | 6 pin * | 3,4,7,8 |
| 10 pin | 1 - 10 | 4 | 2 pin * | 5,6 ** |
| 6 pin | 3 - 8 | 1 | 6 pin * | 3,4,7,8 |
| 6 pin | 3 - 8 | 2 | 2 pin * | 5,6 ** |

* If crossarms for more pins than these are anticipated within ten years, they should be installed initially but the pins assigned initially should be as stated in right-hand column.

** Where 2 pin sidearms are used in joint construction the pin numbers shall be 3, 4, or 7, 8 depending on which side of the pole the wires are placed. In joint construction the circuit should be on the same side of the poles for the entire line for noise reduction.

13.05 Where an open wire line carries both trunk and subscriber circuits, the trunk circuits should be placed above the subscriber circuits where more than one crossarm is required. Also, the pole pins are the least desirable location for a trunk circuit from the noise standpoint. Where it is apparen that additional trunk circuits will be required in the future subscriber lines using trunk grade facilities may be placed where they can be conveniently used later as trunk circuits.

13.06 Pin position assignments, where carrier is contemplated, should not be made without reference to REA TE & CM-462 and , which contain information as to preferential pin posi- s for various situations. Certain fundamentals must be such as, if there are two carrier systems on a line, use the same type and gauge of wire for crosstalk

13.07 Table B indicates that pins 5 and 6 on 6-pin and 10-pin crossarms should be assigned to the shortest circuit, being the first one to drop off the line. This is because a circuit on these pins is the least desirable from the noise standpoint.

13.08 Crossarm Load Equalization

13.081 Circuits should be assigned to pin positions on crossarms so that the expected loads normally, and during ice storms will be as near equal on the two ends of the crossarms as practicable. In tangent construction ice loads are more important than normal loads on crossarms. At deadends both ice loads and normal wire tension loads are involved, but the loads under ice conditions are up to five times as great as the normal wire tension loads for spans of any length in the heavy and medium loading districts, and up to three times as great in the light loading district. This information is shown in the wire manufacturers' sag and tension data. In tangent construction unbalances due to ice loads may break crossarms or poles if too many pins are vacant on one side of the pole. At deadends unbalances on the two ends of the crossarms due to ice loads or even normal stringing tensions may twist the crossarms on the poles or twist the poles in the ground.

13.082 If all the wires at a deadend are not the same type and gauge, or if some spaces are to be vacant, the engineer should compute the wire deadend loads in foot-pounds on the two sides of the crossarm and equalize the loads on the two sides of the pole by shifting circuit positions on the deadend crossarms. For such computations he should consult the data on deadend pulls provided by the wire manufacturers in their engineering data books. The deadend pulls are more important than the normal tensions for the reasons stated in the preceding paragraph. Crossarm guys are not desirable and should not be used.

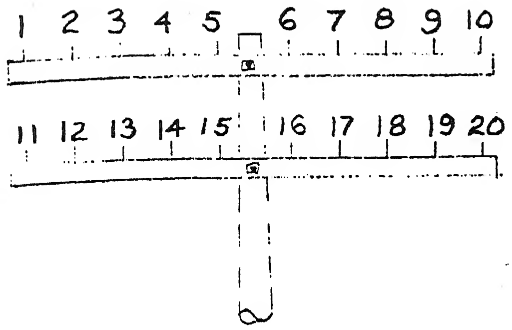
13.083 REA Form 511 specifies that where two or more types and gauges of line wire are on the same pole line the sag of all wires shall be that of the type and gauge of wire requiring the greatest sag. This

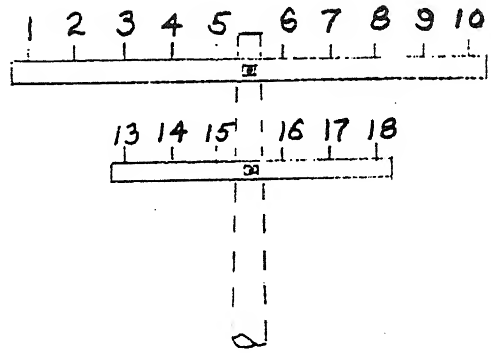
means that the tension of the wire which controls the sag will be as stated in the reference sag and tension tables but the tension in the other wires will be less than given in the reference tables. For example, assume a 500 foot span in the medium loading district where .109-195 galvanized steel and .091-inch aluminum-covered steel wires both are to be on the same crossarm. The required normal sag stated in the references for the steel wire at 60°F is 42 inches and the tension at the sag is 285 pounds. The required sag stated for the aluminum-covered steel wire is 46 inches and the tension at the sag is 150 pounds. When the sag of the steel wire is increased to the 46 inches as required by REA Form 511, its tension will be reduced to about 262 pounds when calculated using the formula in paragraph 6.011. It is evident from this example that a pair of .109-195 steel wires as wires 1 and 2 would not be balanced by a pair of .091 inch aluminum-covered steel wires as wires 9 and 10 of deadend crossarm. It would be necessary to shift the location of the steel pair nearer the pole on the deadend crossarm to balance the loads, if practicable. A desirable layout on the deadend crossarm only, would be to have the steel pair as wires 5 and 6 and two aluminum-covered steel pairs with one pair on each side of the steel pair.

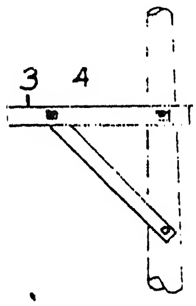
## 14. GUARD CROSSARM APPLICATIONS

14.01 Guard crossarms should be considered on joint use poles or on power crossing poles where the telephone line has a change of grade upward at the pole. The telephone wire might spring upward and strike a power wire if a tie or pin becomes loose or an insulator breaks on such a pole. Such a crossarm will also afford protection to the construction crews during the tensioning operation. The need for a guard crossarm may be determined from the equation given in Appendix A. Figure 2 gives suggested methods suitable for guard crossarm application on 2 pin, 6 pin, and 10 pin crossarms.

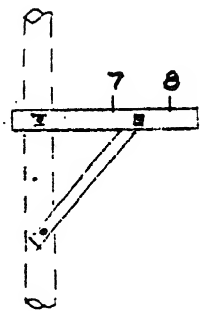
14.02 Where a pole line having two or more crossarms will be endangered under the conditions stated in the above paragraph and a guard crossarm is specified, the wires on the lower crossarms should be protected by placing .109-inch or larger steel wire vertically between the crossarms. These wires should be placed between the end pins and the ends of the crossarms. Two wraps should be made around the crossarms and staples should be placed over the wraps. The wire ends should be entwined around the vertical portion of the guard wires between the crossarms.

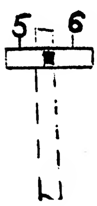



Joint-use
single circuit

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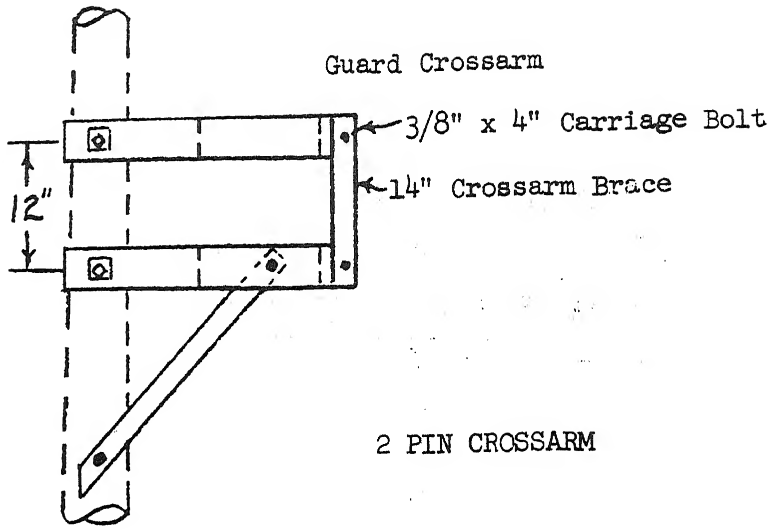
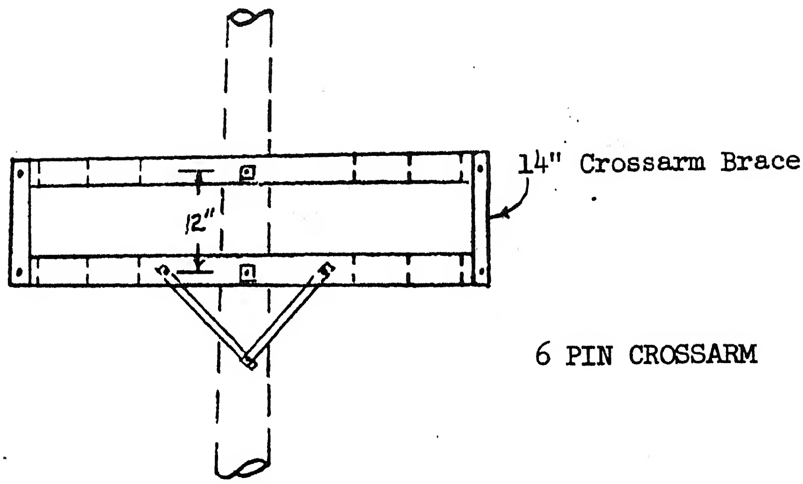
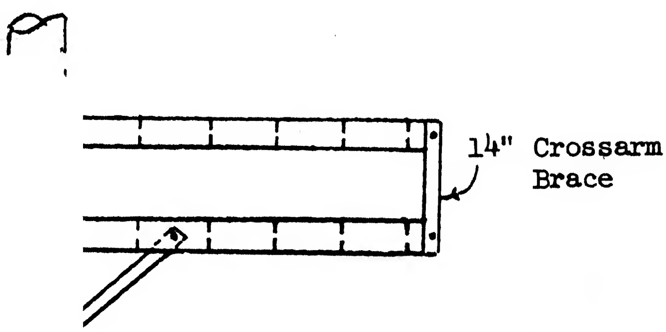


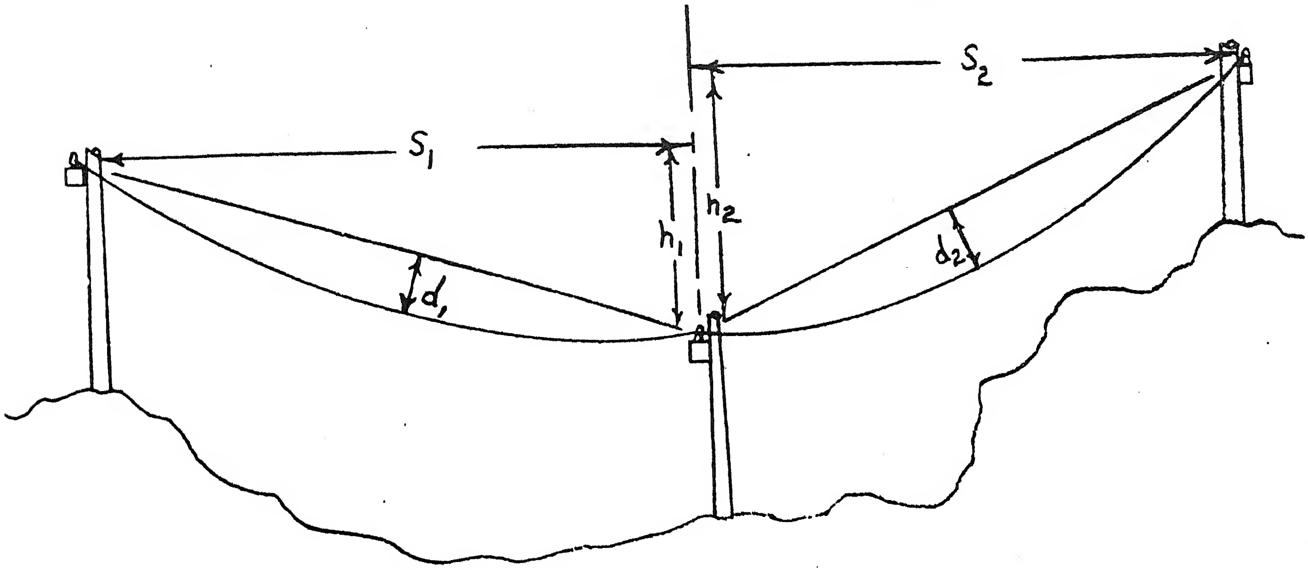

2 PIN CROSSARM




6 PIN CROSSARM




10 PIN CROSSARM




If $\frac{S_1 + S_2}{2} - \frac{S_1 h_1}{8d_1} - \frac{S_2 h_2}{8d_2}$ is positive: no guard crossarm is required.

If $\frac{S_1 + S_2}{2} - \frac{S_1 h_1}{8d_1} - \frac{S_2 h_2}{8d_2}$ is negative: a guard crossarm is required.

Note: $d_1$ and $d_2$ are the sags in feet at the lowest temperature to be expected for the locality. They are the sags taken from the manufacturer's tables for a level span of the same length.

$S_1$, $S_2$, $h_1$, $h_2$ are all in feet.

Determination of Need for Guard Crossarm

APPENDIX A

TABLE [illegible]
Line Wire Characteristics

| | Class of Galv. | Steel Wire Conductor .109-135 | Steel Wire Conductor .109-155 | Aluminum Covered Steel Wire .091 [illegible] | Copper Covered Steel Wire Conductor [illegible] | Copper Covered Steel Wire Conductor [illegible] |
|---|---|---|---|---|---|---|
| Nominal diameter, inches | All | .109 | .109 | [illegible] | [illegible] | [illegible] |
| Weight, pounds per foot | All | .0322 | .0322 | .0165 | .0128 | .0175 |
| Min. Breaking Strength, pounds | All | 1213 | 1800 | 1261 | [illegible] | [illegible] |
| Fatigue endurance limit, psi | All | $46 \times 10^3$ | $55 \times 10^3$ | $43 \times 10^3$ | $39.5 \times 10^3$ | $41 \times 10^3$ |
| Temperature coeff. of expansion, per $^{o}F$ | All | $64.5 \times 10^{-7}$ | $64.5 \times 10^{-7}$ | $7.2 \times 10^{-6}$ | $7.2 \times 10^{-6}$ | $6.61 \times 10^{-6}$ |
| D-C resistance at $68^{o}F$ (Ohms per loop mile) | A | 76.5 | 77.6 | 65.4 | 54.5 | 61.4 |
| Recommended Maximum Span H | All | 350 | 600 | 480 | 320 | 540 |
| M | All | 540 | 650 | 750 | 560 | 700 |
| L | All | 650 | 700 | 800 | 560 | 700 |
| Resistance to Corrosion | | | | | | |
| Industrial atmospheres including: chemical processing, coal mines, oil refineries, oil wells, paper mills, sour gas fields and sulphur mines | A | Poor | Poor | | | |
| | C | Fair | Fair | | | |
| | - | | | Good | Poor | Poor |
| Fertilizer Plants | A | Poor | Poor | | | |
| | C | Fair | Fair | | | |
| | - | | | Fair | Fair | Fair |
| Marine Atmospheres | A | Poor | Poor | | | |
| | C | Fair | Fair | | | |
| | - | | | Not Evaluated | Poor | Poor |
| Rural Atmospheres | All | Good | Good | | | |
| | - | | | Good | Good | Good |

TABLE 1 - Continued

Line Wire Characteristics

| | Copper-covered Steel Wire Conductor | | | | |
|---|---|---|---|---|---|
| | .102-30% EHS | .104-40% HS | .104-30% HS | .104-40% EHS | .080-30% EHS |
| Nominal diameter, inches | .102 | .104 | .104 | .104 | .080 |
| Weight, pounds per foot | .0288 | .0300 | .0300 | .0300 | .0178 |
| Min. breaking strength, pounds | 1460 | 1177 | 1283 | 1325 | 770 |
| Fatigue endurance limit, psi | $30 \times 10^3$ | $24 \times 10^3$ | $24 \times 10^3$ | $30 \times 10^3$ | $24 \times 10^3$ |
| Temperature coeff. of expansion, per $^oF$ | $7.2 \times 10^{-6}$ | $7.2 \times 10^{-6}$ | $7.2 \times 10^{-6}$ | $7.2 \times 10^{-6}$ | $7.2 \times 10^{-6}$ |
| D-C resistance at 68$^oF$ Ohms per loop mile | 35.9 | 24.6 | 32.3 | 24.6 | 41.6 |
| Recommended Maximum Span H | 500 | 360 | 400 | 400 | 240 |
| M | 600 | 550 | 600 | 600 | 400 |
| L | 600 | 550 | 550 | 600 | 560 |
| Resistance to Corrosion<br>Industrial Atmospheres including: Chemical processing, coal mines, oil refineries, oil wells, paper mills, sour gas fields, and sulphur mines | Poor | Poor | Poor | Poor | Poor |
| Fertilizer Plants | Fair | Fair | Fair | Fair | Fair |
| Marine Atmospheres | Poor | Poor | Poor | Poor | Poor |
| Rural Atmospheres | Good | Good | Good | Good | Good |